Title
From Theory to Practice: Lessons Learned from an Advanced M&V Commercial Pilot

Authors
Crowe, Eliot
Granderson, Jessica
Fernandes, Samuel

Publication Date
2023-04-30

Peer reviewed

DOI: 10.20357/B73591

From Theory to Practice: Lessons Learned from an Advanced M&V Commercial Pilot

Eliot Crowe
Jessica Granderson
Samuel Fernandes

Lawrence Berkeley National Laboratory

Energy Technologies Area
September 2010

Please cite as:
Crowe, E., Granderson, J. and Fernandes, S. (n.d.). From Theory to Practice: Lessons Learned from an Advanced M&V Commercial Pilot. In: *2019 International Energy Program Evaluation Conference*. Denver: IEPEC.

From Theory to Practice: Lessons Learned from an Advanced M&V Commercial Pilot

Eliot Crowe, Jessica Granderson, Samuel Fernandes,
Lawrence Berkeley National Laboratory, Berkeley, CA

ABSTRACT

Advanced measurement & verification (M&V), or M&V 2.0, is an energy data analysis method using advanced metering infrastructure (AMI) data in combination with analytics to quantify energy efficiency project savings. Advanced M&V is viewed as an enabler for underutilized behavioral, retrocommissioning, and holistic multi-measure efficiency efforts, as quantifying savings for these programs with existing methods has typically been very challenging.

Despite its promise, there are still several unanswered questions about the use of advanced M&V such as: How accurately can these tools quantify energy savings? How can advanced M&V satisfy regulatory requirements for rigorous savings estimates? Where and how does advanced M&V intersect with traditional impact evaluation and the principles of 'embedded' evaluation, measurement & verification (EM&V)? Pilots are being pursued in various regions and program contexts to address these research questions. However, results from these pilots are rarely made public, meaning that lessons may not be widely shared and the scope of analyses varies widely.

The paper presents encouraging results from a recent advanced M&V pilot and discusses key process-related aspects such as managing AMI data and refining analysis methodologies. An approach to reviewing and classifying projects based on savings characteristics and magnitude is demonstrated, as a potential risk management tool. The authors also demonstrate how advanced M&V can identify underperforming projects and non-routine events in a timely manner. The paper also outlines lessons learned from this and other recent pilot activity and barriers to be overcome in moving toward the goal of widespread adoption of holistic meter-based programs.

Introduction

The growing availability of interval energy use data together with the rapid expansion of energy analytics offerings presents tremendous promise to both enable efficiency savings and automate savings quantification. Industry-wide, there is a desire to streamline the M&V process; utility program evaluators have shown interest in advanced M&V but have needed guidance on different application methods and tools applicable to those methods (Molina et al. 2017). In addition, as we work to meet aggressive building energy reduction goals at national and state levels, there is an increasing interest in moving toward performance-based outcomes - whether in codes, utility incentive programs, or operational energy goals. Innovative utility "pay-for-performance" programs are emerging, and these measured savings approaches can reach underserved markets such as commercial real estate (Pearce et al. 2018). In the context of program evaluations it has been suggested that accurate, direct, census-based M&V of entire populations rather than sampling is more consistent with broad climate change mitigation goals and policies (Cross et al. 2017). Prior work has developed and tested advanced M&V approaches to improve the project savings estimation process through the analysis of time-series meter data (Granderson et al. 2015, Granderson et al. 2016). This work has shown through statistical test procedures that these automated techniques can be accurate and robust in characterizing and predicting building energy use.

Even though there has been a rapid advancement in the types of new algorithms that can be used within advanced M&V tools, and efforts to pilot and deploy them, there are still a number of barriers that need to be overcome to enable their widespread deployment. For example, there is a need for more automated methods to address non-routine events[1] (NREs) (SBW 2019), with some research already progressing on that topic (Touzani 2019). Advanced M&V is not proposed as a direct replacement for a comprehensive EM&V process, however, it may be considered as an element of EM&V or as a means for utilities to get an early indication of energy impacts for their programs.

Background

Given the increasing industry interest in advanced M&V, driven by the availability of data and advanced analytics, efficiency industry stakeholders have recently been exploring advanced M&V pilots across the United States (U.S.). A Connecticut commercial advanced M&V pilot was initiated in 2017 and included a diverse group of project partners including utilities and public sector organizations. The overall objective of the pilot was to demonstrate the use of advanced M&V methods on existing utility programs to gain early insight into the actual savings for implemented efficiency measures, and explore the concept of embedded EM&V[2]. Specifically, the main objectives of the pilot project were to:

1. Compare the savings derived from advanced M&V and program ex-ante savings estimates.
2. Compare the level of effort between advanced M&V and program ex-ante savings estimates.
3. Gain an understanding of the practicalities of applying advanced M&V within a utility program environment.

The Connecticut pilot was implemented concurrently with other advanced M&V pilot activity that the authors are engaged in, in California and Washington. Relevant findings from these complementary efforts are also briefly summarized in this paper.

Connecticut Advanced M&V Commercial Pilot

The Connecticut advanced M&V pilot comprised multiple steps, beginning with pilot site selection, followed by data acquisition, data analysis, and finally the interpretation and documentation of the results. After pilot site selection, the utility partners provided updated electric interval data for pilot sites every quarter. The utility partners also provided information on the measure installation dates and periodic updates on any other site occurrences that may have impacted project performance. For any projects with measures installed, the process was to [a] determine baseline period dates and the start of each project's "performance period" after measure installation, [b] create a baseline model, and [c] track savings for the performance period. Savings tracking analysis was repeated each time new interval data was provided by the utilities. Details of each of the pilot steps are provided below.

[1] Non-routine events are temporary or permanent changes in building energy use that are not attributable to changes in the independent variables used in an advanced M&V baseline model, or to efficiency measures that are installed

[2] Embedded EM&V is a concept whereby program evaluation is conducted concurrent with program implementation using granular energy data and advanced analytics to monitor impacts at the meter in comparison with ex-ante claimed project savings

Pilot Site Selection

The Connecticut advanced M&V pilot was initiated in 2017, commencing with pilot site selection. Utility partners reviewed project pipeline lists to identify upcoming projects that were expected to save at least 5% of whole building energy consumption. The 5% minimum savings threshold was set in order to have confidence in distinguishing savings from noise in the energy data; in the absence of a reliable savings uncertainty calculation method for hourly data models, 5% was chosen as a reasonable savings threshold for pilot site selection. Advanced M&V has shown potential for quantifying savings for complex projects, such as addition of controls, multiple measures, and retrocommissioning. Upon review utility partners did not have many of these project types in their pipelines so the pilot was opened up to other project types such as lighting retrofits. Thirty-four pilot projects were identified that were expected to achieve 5% savings or more, and historical interval meter data was provided for each of the sites where projects were being implemented. Using 12 months' baseline data from the sites, a baseline model was created and the quality of the model was assessed using three model fitness metrics:

- Coefficient of determination (R^2), target >0.7;
- Coefficient of Variation of the Root Mean Squared Error (CV(RMSE)), target <25%;
- Normalized Mean Bias Error (NMBE), target within -0.5% to +0.5% range.

The advanced M&V mathematical model used in this pilot is the Time of Week and Temperature Model (TOWT) model (Mathieu et al 2011; Price 2010). The TOWT modeling method is a regression model that includes time of week and a piecewise-continuous temperature response with several change points. The TOWT modeling method has been demonstrated to be accurate and robust across a variety of building types and regions (Granderson et al 2016). This model has also been adapted for use as a component of CalTRACK 2.0, a set of empirically tested methods intended to standardize the way normalized meter-based changes in energy consumption are measured and reported (CalTRACK 2018). To validate the use of the TOWT model for this region (particularly given that outside air and time of week are the sole independent variables), baseline models were created for 137 Connecticut commercial buildings, with the result that 71% of models met model fitness criteria. This pass rate is consistent with other related research by the authors which has typically found pass rates between 70% and 85%, suggesting that the TOWT method is a reasonable modeling method for this region.

Overall, 28 out of 34 project sites proposed for the pilot (82.3%) produced baseline models that met the fitness screening criteria. Five of these sites failed because generation from onsite photovoltaic panels could not be separated from the site energy consumption, resulting in poor correlation of energy use with outside air temperature. The majority of the efficiency measures that were installed at the pilot sites[3] were lighting projects (upgrades or controls), followed by upgrades to the heating and cooling system motors. Amongst the cohort of sites, grocery stores were the most prevalent building type in the pilot (n = 9), followed by office buildings (n = 6).

[3] Advanced M&V pilot was solely concerned with estimating savings from pre-existing utility-sponsored projects; measure recommendation and installation was outside of the scope of the M&V pilot.

Data Analysis

Figure 1 shows the data analysis time periods applied to each project in the advanced M&V pilot. Baseline and performance periods are established for each project and 12 months' baseline and at least 9 months of performance period data is used for the analysis. Data from two months prior to the reported measure implementation date is removed from the dataset for all sites to allow for any discrepancy between reported and actual implementation dates. This time period, also known as the 'project blackout period', is removed to ensure sufficient time was given for the measure to be installed and to ensure that the installation period does not overlap with the period for which the energy savings are being measured.

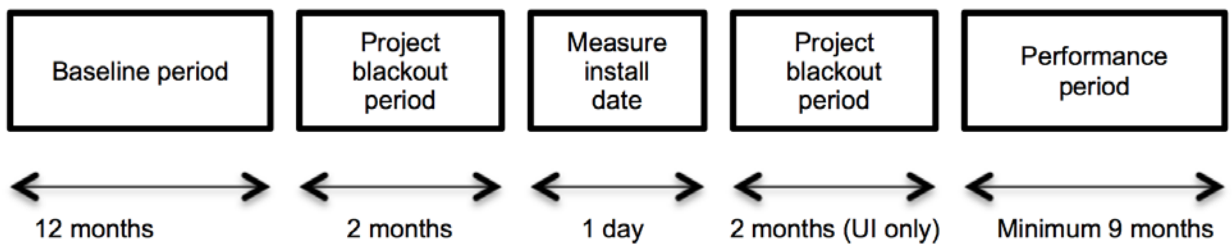

Figure 1. Advanced M&V data analysis time periods

Advanced M&V energy savings are estimated by subtracting actual energy consumption from model-predicted consumption during the performance period; predictions are based on actual hourly ambient temperatures in the performance period; this is known as the "avoided energy use" approach to quantifying savings (IPMVP 2012). Savings analysis was carried out every quarter through 2018 and into 2019, and savings estimates were reviewed with the utility partners.

Review Process for Advanced M&V Savings

There are no standardized procedures for reviewing ongoing advanced M&V savings estimates, and there are many considerations that include both qualitative as well as quantitative factors. For this pilot time series plots and cumulative savings (CUSUM) charts were reviewed. A CUSUM chart is used for tracking the cumulative sum of the difference between actual energy consumption and model-predicted consumption. The profile of a CUSUM chart can provide insights into how a measure is saving energy. For example, a lighting retrofit might be expected to see a roughly steady, straight CUSUM chart as it is more dependent on schedule than ambient weather conditions. However, savings from an HVAC improvement measure might be expected to vary by season.

Advanced M&V site savings estimates for the Connecticut pilot went through a 3-step review sequence that addresses the following questions:

- Are the expected savings (based on ex-ante estimates) 5% or greater?
- Is the CUSUM chart profile relatively 'clean,' i.e., relatively straight and without major inflections that might suggest NREs or atypical operating schedules?
- What is the magnitude of difference between the advanced M&V savings estimate and the ex-ante savings estimate?

Time-series plots of actual versus predicted energy consumption are also used in the savings review process, and in some cases are useful in understanding when anomalies occurred. For example, in one case it is observed that energy consumption increased significantly on Saturdays starting from a particular date.

Advanced M&V Pilot Savings Results

Final advanced M&V savings estimates were established for 26 pilot sites (projects at 2 sites were discontinued after the pilot began) using 9-12 months of performance period data, and were compared to ex-ante estimates for each site (ex-ante estimates were based on engineering calculations). In cases where less than 12 months of performance data were available, advanced M&V savings estimates were extrapolated to an annualized value based on average savings per day (a simplistic approach, but considered adequate for a general comparison). Based on comparison with ex-ante estimates and review of the advanced M&V savings charts, the 26 pilot sites are grouped into four categories:

- Category 1: Sites with a consistent savings profile (i.e., a fairly linear CUSUM) and difference between advanced M&V and ex-ante estimates within 20%[4] (6 projects).
- Category 2: Sites with a consistent savings profile, and advanced M&V results consistently much lower than the ex-ante estimates (> 35%) (5 projects).
- Category 3: Sites with an irregular savings profile that could indicate the presence NREs or atypical building use or scheduling (9 projects).
- Category 4: Sites with low expected savings (<5%) that would not generally be considered suitable for site-level meter-based savings approaches due to signal-to-noise challenges (it is difficult to discern savings with advanced M&V on projects with savings of 5% or less). These sites were initially expected to install more measures and have greater savings than were actually installed during implementation (6 projects).

Further details on each of these categories are provided below.

Category 1: The projects at these six sites comprised lighting measures (lighting upgrades or controls). An example is shown in Figure 2, where the ex-ante annual savings estimate was 234,032 kilowatt-hours (kWh), while the advanced M&V annual savings estimate was 236,546 kWh, i.e., a percent difference of 1%. The CUSUM chart for this site shows a relatively steady linear slope (Figure 2b).

[4] 20% was not a pre-determined threshold for defining Category 1. Advanced M&V savings estimates were reviewed for all sites with a clean CUSUM profile, and it was considered that 20% was a suitable upper limit for advanced M&V to be considered reasonably well-matched to the ex-ante estimate. The next highest value was 35% deviation in savings estimate, which was considered a suitable lower limit for projects that may be worthy of additional investigation into the causes of the deviation.

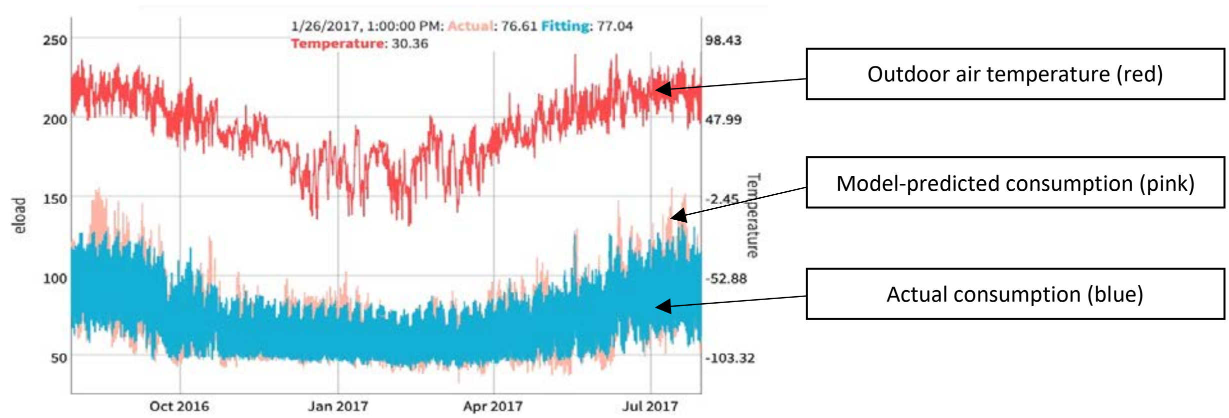

Figure 2a. Example of a retail store baseline model with a lighting upgrade project. There is high degree of overlap between actual consumption and model-predicted consumption, providing a visual complement to the use of quantitative model fitness metrics.

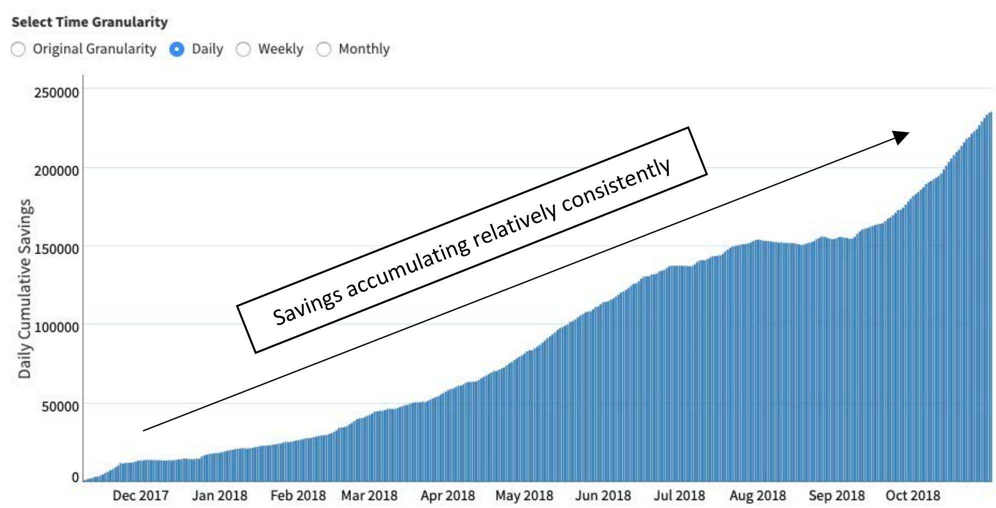

Figure 2b. Example CUSUM chart indicates relatively steady savings accumulating over the performance period.

Category 2: In five cases advanced M&V produced a relatively clean, straight CUSUM profile but savings are significantly lower than the ex-ante estimate (35%-60% lower). These projects comprise lighting controls and upgrade projects. The savings profile and magnitude of difference in savings estimates suggested possible inaccuracies in the calculations used in the ex-ante estimates (such as assumed hours of use), as opposed to model error or NREs.

Category 3: In this group of nine project sites savings profiles are non-linear, and indicate the possible presence of NREs or atypical building use or scheduling. Figure 3 shows an example of a CUSUM profile that indicates a possible NRE. No correlation was observed between measure type/mix and irregular CUSUM profiles.

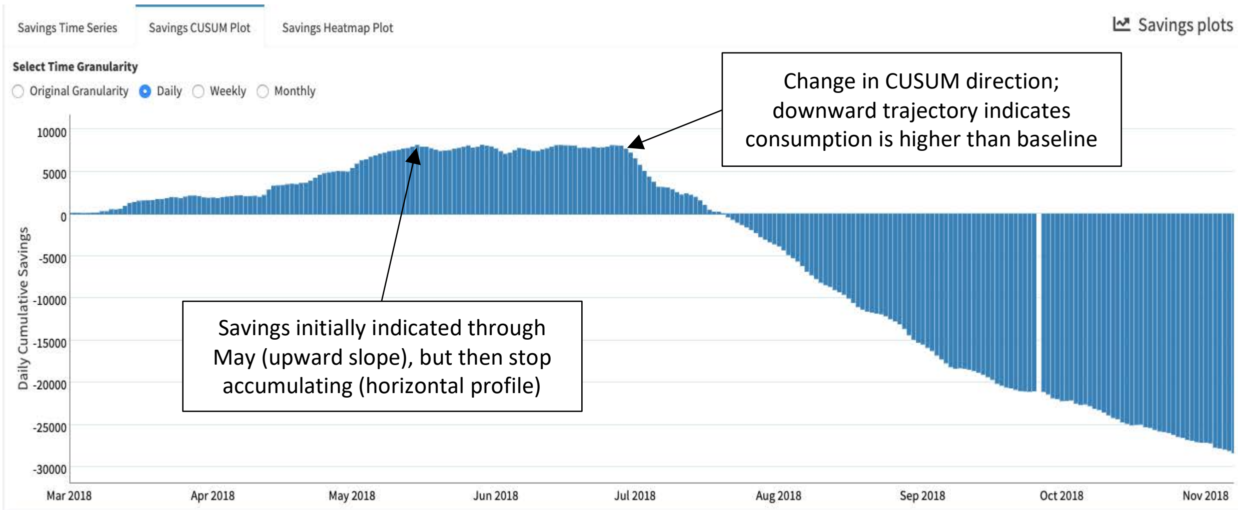

Figure 3. CUSUM chart for grocery store, indicating possible NREs in May and/or July.

Category 4: As noted earlier, these six sites were not considered good candidates for whole-building meter-based M&V due to signal-to-noise challenges.

Aggregated Savings Analysis

To further explore how savings tracking might be conducted for cohorts of buildings, we developed aggregate savings estimates for each of the four project sub-categories identified above and in Table 1. The comparisons in Table 1 might be useful for utility program managers looking to assess potential performance risks in advance of formal program evaluations or pay-for-performance program payments. For example, the six projects in Category 1 might be considered close enough that no action need be taken, projects in Category 2 may warrant a review of assumptions in the ex-ante savings calculations, and actions on other categories may be determined based on the magnitude of savings expected (i.e., projects with significantly higher/lower expected savings may justify an onsite investigation of installed measures). As noted earlier, the advanced M&V savings estimates for Category 4 are considered unreliable, but are included in Table 1 to illustrate that aggregating the results in this sub-category did not counteract possible bias at the individual site level (i.e., within this pilot's data set, 'positive' savings estimation bias on some sites are not counterbalanced with 'negative' bias on others).

Table 1. Aggregated kWh savings estimates based on savings characteristics

	M&V savings estimate (kWh)	
Project savings characteristics	**Ex-ante savings estimate (annualized)**	**Advanced M&V (annualized)**
Category 1: Advanced and ex-ante estimates within 20%	3,236,100	2,728,540
Category 2: Difference between advanced and ex-ante estimates >35%	2,799,540	1,537,768

Category 3: Possible NREs	3,626,699	188,963
Category 4: Savings too low; not appropriate for advanced M&V under this pilot	652,515	1,503,350

For additional comparison of results at aggregate level, Table 2 below shows the aggregated kWh savings estimates for each utility's cohort of buildings, based on ex-ante and advanced M&V approaches. For comparison, Table 2 also includes total advanced M&V savings estimates where any negative savings values are counted as zero[5].

It can be seen that the total aggregated ex-ante estimates (10.3 million kWh) are significantly higher than both the advanced M&V estimates (6.0 million kWh) and the advanced M&V estimates where negative savings are treated as zero (6.8 million kWh).

Within the pilot data set, interpretation of the aggregate results was challenging due to the limited number of pilot sites. Given the small dataset and the mix of project types and sizes, extreme results on an individual project can disproportionately skew the aggregate totals. For example, two projects from Utility-1 had a combined impact of –2,369,520 kWh on aggregate savings whereas one project from Utility-2 had an impact of +1,405,256 kWh.

Table 2. Aggregated kWh savings estimates for ex-ante and advanced M&V

Data source	Ex-ante annual kWh savings estimate	Advanced M&V (annualized) kWh savings estimate	Advanced M&V (annualized) kWh savings estimate, negative savings taken as zero
Utility-1	7,549,616	3,397,410	3,940,999
Utility-2	2,765,238	2,561,184	2,844,226
Total	10,314,854	5,958,594	6,785,226

Comparison of labor effort required for advanced M&V versus ex-ante savings estimates

Labor effort for advanced M&V was recorded for the pilot, broken down into three main components: Data processing, modeling, and collating results. Savings calculations were conducted quarterly, with the final round of savings analysis taken as representative of time requirements for advanced M&V in this pilot setting. Earlier rounds of analysis were not taken as representative due to anomalies, for example:

- The source of weather data initially used (Weather Underground) became unavailable midway through the pilot, and analyses had to be re-coded to use a new source (NOAA).

[5] In the absence of accepted guidance on how to treat 'negative savings,' site savings were adjusted to zero in five cases, to observe the impact on aggregated savings analysis.

- Utility-provided data file formats were not consistent from one round of analysis to the next, introducing significant additional time requirements to re-standardize the data for use in the advanced M&V tool.

Table 3 summarizes the time taken to conduct advanced M&V for the final round of analysis (this represents a single round of advanced M&V savings estimates, as opposed to the total time spent across the whole pilot period).

Table 3. Time taken to conduct advanced M&V for the pilot projects (n= 26 projects)

Advanced M&V activity	Total time for advanced M&V	Average time per project	Percent of total time
Data Processing	109 hours	4.2 hours	70%
Modeling	3 hours	0.1 hours	2%
Collating Results	44 hours	1.7 hours	28%
Total	156 hours	6 hours	100%

The time to conduct advanced M&V (average six hours per project, as shown in Table 3) is not affected by the number or complexity of measures installed, as is the case for traditional savings estimation methods. Eversource and UI estimated 80-100 hours of effort to develop ex-ante savings estimates, based on a single comprehensive retrofit project with several measures; most effort is for gathering project information through site visits, documentation review, etc. A single measure project would be quicker (estimate <40 hours), while a retrocommissioning project may be longer, because it involves more complicated systems and more in-depth reviews. Given the onsite component and documentation reviews it is unsurprising that ex-ante calculations were estimated to take significantly more time than advanced M&V. It should also be noted that advanced M&V time estimates do not account for non-routine adjustments that would be needed for some projects, but even accounting for that it would be expected that advanced M&V requires less effort than engineering calculations.

Additional Insights from Other Advanced M&V Pilots

In parallel with the Connecticut advanced M&V pilot, the authors are pursuing related research activities in other regions. Selected insights from these activities are summarized below:

- **Seattle City Light (SCL):** SCL is implementing a similar pilot design to Connecticut (with co-funding from Bonneville Power Association). Final advanced M&V results have not yet been determined, but similar to Connecticut the SCL pilot is seeing a mix of savings profiles across 19 targeted pilot buildings. The SCL pilot projects generally involve more complex measures, sometimes implemented sequentially over a longer time frame, resulting in greater challenges in determining actual measure implementation dates and higher chance of NREs occurring.
- **California Public Utilities Commission (CPUC):** Using data from over 600 buildings provided by several California utilities the authors explored the potential for developing accurate baseline models using hourly and daily gas data, with a particular focus on restaurants. Initial results for

hourly modeling of restaurants are promising, with weaker performance for other facility types and for daily models. It is possible that restaurants' gas consumption is strongly influenced by operating schedules, leading to better model fitness compared to other building types that have a less consistent relationship with both schedule and weather (Berkeley Lab 2018).

- **Sacramento Municipal Utility District (SMUD):** As a first step toward understanding how advanced M&V modeling can help manage feeder and transformer level infrastructure investments, SMUD created hourly electric baseline models for over 48,000 commercial building meters. Building type and size had a significant impact on model fitness. Out of 11 business types, 73% of restaurants meet model fitness criteria, while at the other end of the scale only 16% of schools meet criteria. In general, buildings classed as large and medium are easier to model accurately than small buildings; for example, 69% of large office models and 29% of small building models meet fitness criteria (Berkeley Lab 2018).

These pilot efforts, in combination with the Connecticut pilot, demonstrate the progress being made with advanced M&V, and highlight the open issues for advanced M&V to reach scale. They also demonstrate the interest from many stakeholders across the U.S. in advanced M&V, and the varied ways in which they are seeking to use advanced M&V modeling techniques.

Conclusions

The Connecticut pilot and other recent pilot activity has provided insights into the benefits, practicalities, challenges, and labor implications of implementing advanced M&V within a utility program context. The pilot demonstrates an approach to classifying projects based on quantity of savings and qualitative aspects of the savings profile. A categorization scheme such as used in the Connecticut pilot may be useful for utilities implementing pay-for-performance programs or performing embedded EM&V for ongoing programs. Further, the pilot demonstrates the value of advanced M&V in identifying NREs in a timely manner, and providing early identification of projects where savings are significantly lower than expectations. Such insights may be valuable to utilities in managing their evaluation risks, and to program evaluators considering a move toward census-based M&V across whole program portfolios.

As expected, data management proves to be the most time-consuming aspect of applying advanced M&V. Despite that, advanced M&V required less effort than ex-ante savings estimates under this pilot, and for more complex projects the time savings would be even greater, even if adjustments are required for NREs. As advanced M&V moves from pilot to scaled deployment, more consistent meter data management system querying and data processing methods would reduce the effort required. Utilities would also need to review record-keeping around key project dates and allow for projects to be easily mapped to specific meters to ensure that full energy impacts are captured. Given that advanced M&V can have several applications, such as pay-for-performance program savings estimation, embedded EM&V, and as a component of traditional EM&V, direct comparison of effort between advanced M&V and ex-ante savings estimates is not the most critical comparison metric. The benefits of advanced M&V in terms of timeliness of insights, accuracy, and ability to qualitatively assess savings profile may be more important to stakeholders than a direct comparison of effort.

Advanced M&V, as applied through this pilot, is not proposed as a direct replacement for a comprehensive EM&V process. However, it may be considered as an element of EM&V, or as a means for utilities to get an early indication of energy impacts for their programs. While not explored in this pilot, there is significant additional potential for advanced M&V to quantify load shape changes, which is of increasing value to regulators. Sharing knowledge from pilots such as these will assist in bringing the industry to a common understanding of how advanced M&V can complement existing programs and processes to streamline M&V and assist with scaling performance-based energy efficiency programs.

Acknowledgements

This work was overseen by the Connecticut Department of Energy and Environmental Protection, with funding from the U.S. Department of Energy. Additional support was provided by the Assistant Secretary for Energy Efficiency and Renewable Energy, Building Technologies Office, of the U.S. Department of Energy under Contract no. DE-AC02-05CH11231. The Connecticut pilot project team consisted of the Connecticut Department of Energy and Environmental Protection, Eversource Energy, United illuminating, and the Northeast Energy Efficiency Partnerships.

References

CalTRACK. 2018. *"CalTRACK Technical Documentation: Modeling Hourly Methods."* Retrieved from: http://docs.caltrack.org/en/latest/methods.html#section-3-b-modeling-hourly-methods

Cross, E. L. 2017. *"Counterfactuals, Damned Lies, and Statistics: Impact Evaluation in the Era of Big Data."* In proceedings of the 2017 International Energy Program Evaluation Conference.

Efficiency Value Organization. 2012. *"International Performance Measurement and Verification Protocol: Concepts and Options for determining energy and water savings."* Volume 1, pp.14.

Granderson, J., Price, P. N., Jump, D., Addy, N., & Sohn, M. D. 2015. *"Automated measurement and verification: Performance of public domain whole-building electric baseline models."* Applied Energy, 144, 106-113.

Granderson, J., Touzani, S., Custodio, C., Sohn, M.D., Jump, D., and Fernandes S. 2016. *"Accuracy of automated measurement and verification (M&V) techniques for energy savings in commercial buildings." Applied Energy*, 173, pp.296-308.

Lawrence Berkeley National Laboratory. 2018. *"California Public Utilities Commission Extends M&V 2.0 Analyses to Gas Data."* Case study, retrieved from: https://buildings.lbl.gov/emis/assessment-automated-mv-methods.

Lawrence Berkeley National Laboratory. 2018. *"Sacramento Municipal Utility District Explores Advanced M&V Capabilities."* Case study, retrieved from: https://buildings.lbl.gov/emis/assessment-automated-mv-methods.

Mathieu, J.L., Price, P.N., Kiliccote, S. and Piette, M.A. 2011. *"Quantifying changes in building electricity use, with application to demand response."* IEEE Transactions on Smart Grid, 2(3), pp.507-518.

Molina, M., Nowak, S., Kushler, M. 2017. *"Evolution of EM&V: State experience that looks to the future*." In proceedings of the 2017 International Energy Program Evaluation Conference.

Pearce, E., Dearth, F., Schantz, M. 2018. *"Getting Ahead of the Savings Curve: Utility Pay-For-Performance Program Design for Commercial Real Estate Customers."* In proceedings of the 2018 ACEEE Summer Study on energy Efficiency in Buildings.

Price, P. 2010. *"Methods for analyzing electric load shape and its variability."* Lawrence Berkeley National Laboratory Report Berkeley Lab-3713E.

SBW Consulting, Inc. 2019. *"Commercial Whole Building Demonstration Early M&V Report."* Pacific Gas and Electric, CalMAC ID PGE0434.01.

Touzani, S., Ravache, B., Crowe, E., and Granderson, J. 2019. *"Statistical Change Detection of Building Energy Consumption: Applications to Savings Estimation."* Energy and Buildings,185, pp. 123–136.